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AIR POLLUTION LEVELS AND REGULATIONS IN CANADA

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by

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Energy and Environmental Systems Division
Environmental and Resource Assessment Group

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FOREWORD

This report is one of a series of three prepared for the Office of Fossil Energy (OFE) of the U.S. Department of Energy. Each report deals with one country in which acid deposition, commonly referred to as acid rain, has been a prominent issue of public discussion. The three countries covered in this series of reports are Canada, the Federal Republic of Germany, and the United Kingdom. For each country, air pollution control regulations are trends in air quality and emissions are broadly outlined, then are compared with corresponding regulations and trends in the United States. Since acid rain is the intended field of application, the reports generally deal only with sulfur dioxide, nitrogen oxides, ozone, and total suspended particulates. Carbon monoxide has not been covered, as it is not emitted in significant quantities by the stationary combustors of fossil fuels of interest to OFE. The primary purpose of these reports is to supply reasonable comparisons and information to OFE personnel involved in policy development and speech preparation.

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1 AIR POLLUTION LEGISLATION AND REGULATIONS

1.1 GOVERNMENT AGENCIES WITH ENVIRONMENTAL RESPONSIBILITIES

Responsibility for environmental protection in Canada is shared by the federal and provincial governments. Municipal governments also have environmental protection responsibilities assigned to them by the provincial legislatures.

The Department of the Environment (referred to as Environment Canada) was created in 1971 and is responsible for protecting the country's environment and natural resources. Environment Canada is organized into four services: Atmospheric Environment, Environmental Protection, Environmental Management, and Forestry.[1,2] These services are collectively responsible for three major programs related to the environment:

- The Environmental Services Program, which provides atmospheric data, protects forests and wildlife, and implements pollution control legislation,
- The Parks Canada Program, which operates 28 national parks and over 30 national historic parks and sites, and
- The Administration Program, which interacts with Parliament, develops plans and policy, and distributes publications, films, exhibits, media relations material, and other information.

The Environmental Protection Service in particular is the primary liaison with provincial agencies, industry, other federal agencies, and the general public relating to environmental protection matters. The service develops and enforces environmental regulations, guidelines, codes, and protocols to implement federal legislation. The service regulates air and water pollution, solid waste management and resource recovery, noise, and toxic substances. Its jurisdiction is strictly limited to federal statutes.

Aside from Environment Canada, the Department of National Health and Welfare, and in particular, its Environmental Health Directorate, is responsible for eliminating adverse effects on health and well-being associated with natural and technological causes. Its authority is derived from its enabling legislation as well as from the Hazardous Products Act, the Environmental Contaminants Act, Canada's labor code, and various acts dealing with atomic energy, devices that emit radiation, and food

and drugs. The directorate's work addresses product safety, drinking water, environmental contaminants, occupational health, pesticides, nuclear facility monitoring, environmental radioactivity, radioisotope safety, x-rays, and nonionizing radiation.

At the provincial level, each province has enacted several environmental protection laws and developed regulations to implement them.

1.2 NATIONAL ENVIRONMENTAL PROTECTION LEGISLATION

Canada's National Air Pollution Control Program was brought into force by the passage of Canada's Clean Air Act on June 23, 1971. Under this act, the federal government has the authority to set air quality objectives and national emission standards where a danger exists to health or where international agreements are involved. The federal government also has the authority to regulate the composition of fuels produced in or imported by Canada. National guidelines have been prepared to aid provinces and local governments develop uniform regulations. These guidelines provide a minimum level of air quality control across Canada. Some provinces have adopted these guidelines as their emission standards.[1]

The major types of federal regulations authorized by various sections under the Clean Air Act are:

- National air quality objectives (Section 4),
- National emission guidelines for sources of any class, whether stationary or otherwise (Section 8),
- Regulations covering the composition of fuels (Sections 22 and 23), and
- National emission standards for stationary sources where there is significant danger to health (Section 7) or where international agreements are involved (Section 7), or, in the absence of an international agreement, where there is reasonable cause to believe that the health, safety, or welfare of persons in a country other than Canada is endangered (amended Section 21).

Section 21.1 of the Clean Air Act provides a mechanism for establishing new abatement programs to redress international air pollution problems.[3] As a prerequisite for revising existing pollution control requirements for this purpose, the Minister of the Environment must determine that there is "reason to believe that an air contaminant ... in Canada creates or contributes to the creation of air pollution that may reasonably be expected to constitute a significant danger to the health, safety or welfare of persons in a country other than Canada." Upon this determination, the Minister may then recommend to the cabinet "such specific emission standards ... as he may consider appropriate for the elimination or significant reduction of that danger." The nation affected is allowed to make "representations" with respect to the Minister's

recommendation. The cabinet is then authorized to promulgate the standards recommended, once satisfied on two counts. First is that the Minister has made a "reasonable but unsuccessful endeavor" to secure provincial action. That is, except with regard to federal sources, the Minister cannot make such a recommendation without first determining, after consultation with the governing province, that the problem cannot or will not be eliminated or reduced adequately through provincial action. Second is that reciprocity exists. That is, the foreign country must provide "by law essentially the same kind of benefits in favor of Canada with respect to the abatement or control of air pollution as is provided in favor of that country pursuant to this Act."

Consistent with the preference for voluntary provincial action, Section 21.1 relies initially on the provincial government to take whatever action is needed to "eliminate or significantly reduce" the international problem. If provincial control actions are not forthcoming, however, and if the Environment Minister has made a "reasonable endeavor" to secure provincial cooperation, then the federal government can take the unusual step of establishing federal emission limitations. It is the Minister's responsibility to recommend such emission limits, but they can be promulgated only with the cabinet's approval.

1.3 NATIONAL AMBIENT AIR QUALITY OBJECTIVES

One of the major areas of federal legislative jurisdiction authorized by the Canadian Clean Air Act is the formulation and prescription of national air quality standards, referred to as *objectives*. Under Section 4 of the act, these objectives may reflect three ranges of ambient air quality for any air contaminant: tolerable, acceptable, and desirable.[4] The "tolerable" range denotes contaminant concentration levels that require abatement without delay to avoid further deterioration of the air to a level that would endanger the prevailing lifestyle or ultimately pose a substantial risk to public health. The "acceptable" range is intended to provide adequate protection against adverse effects on soil, water, vegetation, materials, animals, visibility, personal comfort, and well being. The "desirable" range defines the long-term goal for air quality and is the basis for an antidegradation policy for unpolluted parts of the country.

Most of the provinces have incorporated the national ambient air quality objectives, usually at the acceptable level, into their own air pollution control acts. Exceptions are Alberta, which has adopted the federal maximum desirable levels as its provincial air quality standards and Quebec, which has adopted a 1-h sulfur dioxide (SO_2) standard of 50 parts per hundred million (pphm) in excess of the federal maximum tolerable objective of 34 pphm. All other provincial standards are believed to be at the same level as the federal acceptable objectives.

The Canadian ambient air quality objectives are presented in Tables 1.1 and 1.2, along with the U.S. Environmental Protection Agency (EPA) national ambient air quality standards (NAAQS). Personnel at Environment Canada and the Air Resources Branch of the Ontario Ministry of the Environment have suggested a reasonable basis for comparing the Canadian objectives and the U.S. standards. Canadian tolerable levels correspond to action levels in the U.S. air pollution episode control program, i.e., levels posing a risk to public health. Thus, they should not be compared to U.S. ambient standards that aim at

TABLE 1.1 Long-Term National Air Quality Standards: Canadian Objectives versus U.S. NAAQS (annual arithmetic mean, unless otherwise specified)

Standard	TSP ($\mu g/m^3$)	SO_2		NO_2		Ozone	
		$\mu g/m^3$	pphm	$\mu g/m^3$	pphm	$\mu g/m^3$	pphm
Canadian objectives[a]							
Acceptable (maximum)	70[b]	60	2	100	5	30	1.5
Desirable (maximum)	60[b]	30	1	60	3	-	-
U.S. NAAQS							
Primary	75[b]	80	-	100	-	-	-
Secondary	60[c]	-	-	100	-	-	-

[a]Conditions of 25°C and 101.325 kPa were used as the basis for conversion from μ/m^3 to pphm.

[b]Annual geometric mean.

[c]Annual geometric mean; guideline only, for use in assessing state implementation plans to achieve the 24-h standard of 150 $\mu g/m^3$.

protecting public health with a margin of safety. The Canadian acceptable objectives correspond closely with the U.S. primary health-related standards, and the Canadian desirable objectives correspond with the U.S. secondary welfare-related standards.

Based on these correspondences, the U.S. primary annual SO_2 standard of 80 $\mu g/m^3$ exceeds the Canadian annual acceptable objective of 60 $\mu g/m^3$ by approximately 33%, and the U.S. primary 24-h SO_2 standard of 365 $\mu g/m^3$ exceeds the Canadian acceptable objective of 300 $\mu g/m^3$ by 22%. The United States does not have secondary standards comparable to the Canadian desirable objectives for either long- or short-term averaging periods. The U.S. secondary 3-h SO_2 standard of 1,300 $\mu g/m^3$ is also not directly comparable with the Canadian 1-h desirable objective of 450 $\mu g/m^3$. However, the Canadian objective is more restrictive than the U.S. standard, since it specifies a smaller concentration and a shorter averaging period.

With regard to emissions of total suspended particulates (TSP), the U.S. primary annual standard of 75 $\mu g/m^3$ exceeds the Canadian annual acceptable objective of 70 $\mu g/m^3$ by about 7%. While the U.S. secondary annual TSP standard is a guideline only, it is identical to the Canadian annual desirable objective. The U.S. primary 24-h TSP standard of 260 $\mu g/m^3$ exceeds the Canadian 24-h acceptable objective of 120 $\mu g/m^3$ by almost 167%. Canada has no 24-h desirable objective for TSP corresponding to the U.S. secondary 24-h standard of 150 $\mu g/m^3$.

TABLE 1.2 Short-Term National Air Quality Standards: Canadian Objectives versus U.S. NAAQS

Standard	TSP ($\mu g/m^3$)	SO_2		NO_2		Ozone	
		$\mu g/m^3$	pphm[a]	$\mu g/m^3$	pphm[a]	$\mu g/m^3$	pphm[a]
Canadian objectives							
Maximum 24-h arithmetic mean							
Acceptable	120	300	11	200	11	50	2.5
Desirable	-	150	6	-	-	30	1.5
Tolerable	400	800	31	300	16	-	-
Maximum daily 1-h mean							
Acceptable	-	900	34	400	21	160	8
Desirable	-	450	17	-	-	100	5
Tolerable	-	-	-	1000	53	300	15
U.S. NAAQS (24-h arithmetic mean except where noted)							
Primary	260	365	-	-	-	235[c]	-
Secondary	150	1300[b]	-	-	-	235[c]	-

[a]Conditions of 25°C and 101.325 kPa were used as the basis for conversion from $\mu g/m^3$ to pphm.

[b]3-h arithmetic mean.

[c]The maximum hourly average concentration may be exceeded no more often than 1 day per year.

The U.S. primary and secondary annual NO_2 standards of 100 $\mu g/m^3$ are the same as the Canadian acceptable objective and exceed the Canadian desirable objective by almost 67%. The U.S. has no NO_2 standards corresponding to the Canadian short-term objectives.

The United States has no long-term ozone standard corresponding to the Canadian annual acceptable objective of 30 $\mu g/m^3$. The U.S. 1-hr primary and secondary ozone standards of 235 $\mu g/m^3$ exceed the Canadian 1-h acceptable objective of 160 $\mu g/m^3$ by about 47% and the Canadian 1-h desirable objective by 135%. The United States has no ozone standards corresponding to the Canadian 24-h acceptable and desirable objectives of 50 $\mu g/m^3$ and 30 $\mu g/m^3$, respectively.

1.4 EMISSION STANDARDS AND REGULATIONS

Section 7 of the Canadian Clean Air Act authorizes national emission standards to be prescribed for air contaminants that constitute an arguable, significant danger to human health. Once this determination has been made by the Department of National Health and Welfare, Environment Canada is responsible for devising appropriate national emission standards. The department's policy has been to base emission standards on the best available technology for controlling the emissions at the source. To date, Environment Canada has promulgated national emission standards covering lead from secondary lead smelters, asbestos from mining, milling, and manufacturing operations, mercury from chlor-alkali plants, and vinyl chloride from the manufacture of vinyl and polyvinyl chlorides. The standards and regulations promulgated under Section 7 of the Clean Air Act are enforced by the Environmental Protection Service of Environment Canada in cooperation with provincial governments.

Section 8 of the act authorizes promulgation of national emission guidelines for industrial sectors. Task forces set up by the federal government have been used to establish such guidelines in cooperation with the provinces and concerned industrial sectors, and some provinces have prescribed regulations based upon these guidelines.[5] These guidelines cover both new and existing plants, and reflect the best operating practices and best practicable technology in air pollution control pertinent to the industrial processes involved. The guidelines covering fossil fuel power generation are summarized in Table 1.3[6] and are compared with U.S. new source performance standards (NSPS).

Table 1.3 indicates that, given the qualifications explained in the footnotes, the NSPS emission limits are more stringent than the Canadian emission guidelines in some cases -- for TSP and for nitrogen oxide (NO_x) emissions from the combustion of coal-derived fuels.* However, for SO_2 emissions, the Canadian guidelines are more stringent than the NSPS in two instances: (1) for solid and solid-derived fuel combustion relative to the NSPS emission limit of 1.2 lb/10^6 Btu (see footnote g in Table 1.3), and (2) for liquid fuel combustion relative to the NSPS emission limit of 0.8 lb/10^6 Btu (see footnote i in Table 1.3). For NO_x emissions, the Canadian emission guidelines are more stringent in three cases: (1) for solid fuel combustion relative to the NSPS emission limit of 0.8 lb/10^6 Btu, (2) for liquid fuel combustion relative to the NSPS emission limit of 0.5 lb/10^6 Btu, and (3) for gas combustion relative to the NSPS emission limit of 0.2 lb/10^6 Btu.

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*Ambient air quality standards are stated in terms of nitrogen dioxide (NO_2). The term NO_x specifically denotes any combination of nitric oxide (NO) and NO_2 that is emitted by a source. The reason why NO is regulated as a source emission is because it is readily converted to NO_2 in the atmosphere.

TABLE 1.3 Emission Limits for New[a] Fossil-Fuel-Fired Utility Steam-Generating Plants: Canadian National Emission Guidelines versus U.S. NSPS

Pollutant, Fuel Type	U.S. NSPS[b] Emission Limits ng/J	U.S. NSPS[b] Emission Limits lb/10^6 Btu	U.S. NSPS[b] % Reduction of Potential Uncontrolled Emissions	Canadian Guidelines[c] ng/J	Canadian Guidelines[c] lb/10^6 Btu	Canadian Guidelines[c] % of NSPS
TSP: all fuels	13	0.03	99,[d] 70[e]	43	0.1	333
SO_2						
Solid	520[h]	1.2[h]	90[f]	258[g]	0.6[g]	50
	260[h]	0.6[h]	70[h]	258	0.6	100
Liquid	340	0.8	90[i]	258	0.6	75
Gas	86	0.2[j]	90[j]	258	0.6	300
NO_x						
Solid						
Subbituminous coal, coal-derived fuels, or shale oil	210	0.5	-	258	0.6	120
Lignite, bituminous coal, anthracite, or other fuel	260	0.6	-	258	0.6	100
S. Dakota, N. Dakota, or Montana lignite[k]	340	0.8	-	258	0.6	75
Liquid						
Oil or oil/wood residue	130	0.3	-	129	0.3	100
Coal-derived fuels	210	0.5	30	129	0.3	60
Gas						
Gas or gas/wood residue	86	0.2	-	86	0.2	100
Coal-derived fuels	210	0.5	25	86	0.2	40

[a]New units are those whose construction commenced after May 1981 (Canada) or Sept. 18, 1978 (United States). This comparison is based on emission limits only, not on the additional requirements of percentage control of potential uncontrolled emissions by the Canadian guidelines or NSPS.

[b]Limited to units rated at>250 x 10^6 Btu/h.

[c]All emissions are calculated on the basis of a 720-h rolling average.

[d]For solid fuel combustion.

[e]For liquid fuel combustion.

[f]85% for solvent-refined coal fuel combustion.

[g]Recommended limit for units whose uncontrolled SO_2 emissions exceed this amount. An alternative would be to control a minimum of 90% of the uncontrolled emissions from those units whose uncontrolled SO_2 emissions exceed 10 times this amount.

[h]An alternative to 1.2 lb/10^6 Btu with 90% reduction of potential uncontrolled emissions. Noncontinental anthracite combustion units are exempt from a percentage reduction requirement.

[i]Additional requirement for continental units.

[j]Continental units can comply with the emission limit without the additional 90% control requirement.

[k]For units combusting >25% of this coal in slag trap furnaces.

2 ACID DEPOSITION ISSUE

The predominant environmental issue in Canada is acid rain. The Atmospheric Environment Service of Environment Canada is the leading agency for a major federal interdepartmental research program on this problem. The primary program activities include developing and applying long-range transport models, operating a national network for sampling precipitation, and establishing a research network to determine regional levels of sulfur and nitrogen compounds in air and precipitation.

Environment Canada has recently reported acidification problems in the lakes and rivers of eastern Canada.[7] Approximately 45% of the lakes surveyed in Ontario have been categorized as vulnerable to acidification. In many of these surveyed lakes, there have been critical signs of a reduction in the capacity to neutralize acid. A similar situation exists in Quebec. In Nova Scotia, salmon no longer run in approximately 10% of the former salmon rivers, and acidification is beginning in another 20% of these rivers. Environment Canada also maintains that approximately 50% of the forest growth in eastern Canada occurs in areas receiving enough deposition to damage aquatic ecosystems.[7]

Much of the new scientific information on acid rain has to do with effects on forests. At the Maritime Forest Research Center in Fredericton, New Brunswick, controlled experiments have been conducted on the effects of acid rain on germination and early growth of several key tree species. The results show that rain with a pH of 4.6 and a constituent make-up similar to that of rain in the Atlantic region of Canada reduces the germination rate and growth of some species. At the University of Toronto, again in a controlled environment, the fertility of spores of some conifers was found to be affected by rain with an acidity similar to that of the rain in much of eastern Canada. In eastern Quebec and in central Ontario, maple dieback has been occurring. Again, air pollution is implicated.

Canadian scientists have concluded[7] that reducing wet sulfate deposition to less than 20 kg per hectare (ha) per year would protect moderately sensitive lakes and streams from long-term acidification and leave only the most vulnerable ecosystems open to damage. Above this level, environmental damage occurs and can become more severe as the level increases. Further studies are under way to develop environmental objectives (i.e., standards) to avert long-term acidification effects on very vulnerable areas, forest ecosystems, and other sectors. Environmental objectives for short-term deposition effects are also being assessed. Should these objectives be more restrictive than the 20 kg/ha/yr objective, abatement programs would be adjusted accordingly.

Environment Canada has estimated the percentage contribution of Canada and the United States to wet sulfate deposition along the eastern portion of their common border.[7] As Table 2.1 indicates, the United States may be responsible for up to 70% of the total acid deposition in the four eastern Canadian boundary regions. Based on this estimate, Environment Canada has also estimated by how much the wet sulfate deposition would be reduced given various reductions of current SO_2 emission levels by the United States and Canada. These data are presented in Table 2.2. The desired level of less than 20 kg/ha/yr of sulfate deposition may not be achieved in three of the four

TABLE 2.1 Canadian Estimate of the U.S. and Canadian Shares of Wet Sulfate Deposition (% of deposition)

Source of Sulfate Deposition	Canadian Border Region Impacted			
	North Central Ontario	South Central Ontario	Southern Quebec	Southern Nova Scotia
Canada	29-32	32-46	35-58	30-34
United States	68-71	54-68	42-67	66-70

Source: Ref. 7.

TABLE 2.2 Estimated Wet Sulfate Deposition Levels if SO_2 Emissions Are Reduced (kg/ha/yr)

Impacted Region	Current Deposition	Estimated Deposition Based on SO_2 Emission Reduction			
		Reductions by Canada			U.S. and Canadian Reductions, 50% Each
		25%	50%	100%	
North Central Ontario	18-22	17-21	16-20	14-18	11-15
South Central Ontario	29-35	27-33	24-30	20-26	13-19
Southern Quebec	27-33	25-31	23-29	19-25	15-21
Southern Nova Scotia	17-23	17-23	16-22	14-20	15-20

Source: Ref. 7.

Canadian regions even if Canada reduces its SO_2 emissions by 100%. If both countries reduce their SO_2 emissions by 50%, the sulfate deposition goal would be realized in Ontario and marginally realized in Southern Quebec and Nova Scotia. Section 3.2.2 further describes the Canadian SO_2 emission reduction program.

3 AIR QUALITY

3.1 AMBIENT AIR QUALITY

Ambient air quality data for five cities in eastern Canada are presented in Tables 3.1-3.5. The cities were selected because they represent probable sources and/or receptors of transboundary air pollution with respect to the United States. With the exception of Sudbury, Ontario, the cities all have industrial and commercial activity that impacts on air quality. Sudbury was chosen because of its smeltering activity, which has been a subject of concern in transboundary air pollution. The data were obtained from the Canadian National Air Pollution Surveillance Program (NAPS)[8] annual summary reports for 1982, 1983, and 1984. The NAPS is a joint project of the federal and provincial governments that was set up to monitor and assess, on a continuing basis, the ambient air quality in the urban regions of Canada.

The ambient air quality data reproduced in Tables 3.1-3.5 are for TSP, SO_2, NO_2, and ozone, as these are the pollutants of concern with regard to acid rain. The NAPS reports particulate concentrations in micrograms per cubic meter ($\mu g/m^3$) and gaseous pollutant concentrations in parts per hundred million (pphm), although the Canadian federal guidelines for gaseous pollutants are expressed in both $\mu g/m^3$ and pphm (see Tables 1.1 and 1.2). To be consistent, the units of measurement in Tables 3.1-3.5 are the same as in NAPS. The air quality data reported in the tables are comparable with the Canadian federal air quality guidelines (i.e., expressed in terms of the annual mean and the 24-hr and 1-hr maximum values per year). Values that exceed these guideline limits and the U.S. primary NAAQS (health-related standards) are noted.

The data in Tables 3.1-3.5 indicate that the Canadian federal guideline levels were exceeded in a number of instances. These instances were significantly more frequent (1) for TSP and ozone than for SO_2 and NO_2 and (2) for the short-term guidelines than for the annual mean. Ozone appears to be a pervasive problem among the five cities selected for examination. Since only three years of data are represented, it is difficult to speculate on trends. However, it appears that pollutant levels generally decreased from 1982 to 1983, then increased to 1984, though not to levels as high as they were in 1982.

Table 3.1 indicates that Hamilton, Ontario, has a pervasive problem in meeting the annual and short-term maximum acceptable guideline levels for TSP and ozone. The levels of TSP also exceed the U.S. primary annual and short-term standard levels (since the Canadian maximum desirable annual mean objective is slightly lower than the U.S. standard and the Canadian short-term standard is less than half the U.S. standard, as shown in Tables 1.1 and 1.2). The data from the one station that reported ozone levels indicate a problem in meeting Canadian air quality objectives but not U.S. standards.

The air quality data for Montreal in Table 3.2 indicate a problem with meeting the guideline limits for ozone and, to a lesser extent, TSP. In the case of ozone, U.S. standards were also exceeded at a number of stations in 1982 and 1983 but the maximum 1-h value was significantly lower at all sampling stations in 1984. A number of sampling stations reported levels of TSP that exceeded the Canadian 24-h limit but only one

TABLE 3.1 Ambient Air Pollutant Concentrations for Hamilton, Ontario, 1982-1984[a]

Sampling Station[a]	Year	TSP ($\mu g/m^3$)		SO_2 (pphm)			NO_2 (pphm)			Ozone (pphm)		
		Annual Geometric Mean	Maximum 24-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean
60501C	1982	88[b,c]	325[b,c]	1.4[d]	5	18[d]	1.7	8	11	1.7[b]	6[b]	9[b]
	1983	85[b,c]	282[b,c]	1.4[d]	5	15	2.9	8	10	1.9[b]	7[b]	11[b]
	1984	84[b,c]	267[b,c]	1.5[d]	7[d]	18[d]	2.9	6	11	1.8[b]	6[b]	10[b]
60503I	1982	84[b,c]	388[b,c]	-	-	-	-	-	-	-	-	-
	1983	80[b,c]	214[b]	-	-	-	-	-	-	-	-	-
	1984	87[b,c]	356[b,c]	-	-	-	-	-	-	-	-	-
60505R	1982	82[b,c]	257[b]	1.0	7[d]	17	1.7	8	10	-	-	-
	1983	78[b,c]	235[b]	1.2[d]	6	11	2.6	7	14	-	-	-
	1984	92[b,c]	305[b,c]	-	8[d]	13	-	-	-	-	-	-
60511R	1984	-	-	-	-	-	-	4	5	-	-	-

[a]The first digit of each code indicates the province in which the station is located, the second and third the city, and the last two the location within the city. Land use is denoted by C for commercial, R for residential, and I for industrial.

[b]Exceeds Canadian maximum acceptable level.

[c]Exceeds U.S. health-related standard.

[d]Exceeds Canadian maximum desirable level.

Source: Ref. 8.

TABLE 3.2 Ambient Air Pollutant Concentrations for Montreal, Quebec, 1982-1984[a]

Sampling Station[a]	Year	TSP ($\mu g/m^3$)		SO_2 (pphm)			NO_2 (pphm)			Ozone (pphm)		
		Annual Geometric Mean	Maximum 24-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean
50101R	1982	-	-	-	4	20[b]	-	-	-	-	-	-
	1983	-	-	1.0	7	18[b]	-	-	-	-	-	-
	1984	-	-	-	-	-	-	-	-	-	-	-
50102R	1982	44	86	1.0	8[b]	15	-	7	17	-	8[c]	12[c,d]
	1983	42	87	e	5	14	-	8	14	1.2	7[c]	15[c,d]
	1984	40	91	1.2[b]	7[b]	14	2.0	6	9	-	7[c]	9[c]
50103R	1982	56	147[c]	2.0[b]	18[c,d]	44[c]	-	-	-	1.9[c]	7[c]	12[c,d]
	1983	61[b]	178[c]	1.4[b]	17[c,d]	28[c]	-	-	-	-	5[c]	8[b]
	1984	62[b]	161[c]	e	8[b]	23[b]	-	-	-	-	5[c]	10[c]
50104C	1982	60	139[c]	1.2[b]	6	21[b]	2.8	6	11	1.3	7[c]	10[c]
	1983	52	131[c]	e	5	12	2.8	6	13	1.3	7[c]	17[d,f]
	1984	51	202[c]	-	5	11	3.9[b]	16[c]	48[c]	1.2	5[c]	8[b]
50105C	1982	-	126	e	8[b]	22[b]	-	-	-	-	-	-
	1983	-	-	e	-	-	-	-	-	-	-	-
	1984	-	-	e	-	-	-	-	-	-	-	-
50106R	1982	-	-	-	4	14	-	-	-	-	-	-
	1983	-	-	e	5	12	-	-	-	-	-	-
	1984	-	-	-	-	-	-	-	-	-	-	-

TABLE 3.2 (Cont'd)

Sampling Station[a]	Year	TSP ($\mu g/m^3$) Annual Geometric Mean	TSP ($\mu g/m^3$) Maximum 24-h Mean	SO_2 (pphm) Annual Arithmetic Mean	SO_2 (pphm) Maximum 24-h Mean	SO_2 (pphm) Maximum 1-h Mean	NO_2 (pphm) Annual Arithmetic Mean	NO_2 (pphm) Maximum 24-h Mean	NO_2 (pphm) Maximum 1-h Mean	Ozone (pphm) Annual Arithmetic Mean	Ozone (pphm) Maximum 24-h Mean	Ozone (pphm) Maximum 1-h Mean
50108R	1982	36	92	-	5	8	-	8	10	1.7[c]	6[c]	9[c]
	1983	39	79	e	2	8	-	6	10	1.5	5[c]	12[c,d]
	1984	-	-	-	-	-	-	-	-	-	-	-
50109C	1982	107[c,d]	332[c]	e	6	13	-	9	20	-	5[c]	10[c]
	1983	101[c,d]	220[c]	-	7[b]	14	-	13	21	-	4[c]	6[b]
	1984	98[c,d]	232[c]	e	8[b]	17	-	10	18	0.8	9[c]	19[d,f]
50110C	1982	58	250[c]	e	5	9	-	11	40[c]	1.6[c]	7[c]	20[c,d]
	1983	48	106	e	4	10	-	8	13	-	6[c]	12[c,d]
	1984	-	148[c]	e	5	12	1.7	7	11	1.3	6[c]	8[b]
50112C	1982	49	135[c]	e	5	14	2.4	6	11	-	7[c]	12[c,d]
	1983	57	111	-	3	7	2.3	6	11	-	8[c]	12[c,d]
	1984	40	107	e	4	8	2.6	8	14	1.3	7[c]	8[b]
50113R	1982	37	78	e	5	9	2.4	6	14	1.8[c]	7[c]	9[c]
	1983	38	125[c]	e	3	7	2.2	6	16	1.9[c]	8[c]	14[c,d]
	1984	38	106	e	3	12	2.2	11	13	1.8[c]	7[c]	10[c]
50115C	1982	-	-	-	8	13	-	7	10	-	4[c]	7[b]
	1983	-	-	e	6	12	-	9	13	-	5[c]	10[c]
	1984	-	-	e	7[b]	17	3.5[b]	-	13	-	6[c]	9[c]

TABLE 3.2 (Cont'd)

Sampling Station[a]	Year	TSP ($\mu g/m^3$)		SO_2 (pphm)			NO_2 (pphm)			Ozone (pphm)		
		Annual Geometric Mean	Maximum 24-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean
50116R	1982	51	208[c]	e	8[b]	15	1.2	5	9	1.6[c]	7[c]	13[c,d]
	1983	51	160[c]	e	3	8	-	5	11	-	7[c]	13[c,d]
	1984	52	199[c]	e	3	6	2.4	5	10	2.0[c]	6[c]	8[b]
50117	1982	-	-	-	-	-	-	-	-	-	-	-
	1983	-	-	-	-	-	-	-	-	-	-	-
	1984	-	-	-	9[b]	14	-	-	-	-	-	-
50118	1982	-	-	-	-	-	-	-	-	-	-	-
	1983	-	-	-	-	-	-	-	-	-	-	-
	1984	-	-	-	6	15	-	-	-	-	-	-
50119R	1982	-	-	-	-	-	-	-	-	-	-	-
	1983	-	-	-	-	-	-	-	-	-	-	-
	1984	43	130[c]	-	3	7	2.9	7	11	2.0[c]	7[c]	10[c]

[a]The first digit of each code indicates the province in which the station is located, the second and third the city, and the last two the location within the city. Land use is denoted by C for commercial, R for residential, and I for industrial.

[b]Exceeds Canadian maximum desirable level.

[c]Exceeds Canadian maximum acceptable level.

[d]Exceeds U.S. health-related standard.

[e]Calculated means are below 10 parts per billion.

[f]Exceeds Canadian maximum tolerable level.

Source: Ref. 8.

TABLE 3.3 Ambient Air Pollutant Concentrations for Toronto, Ontario, 1982-1984[a]

Sampling Station[a]	Year	TSP ($\mu g/m^3$)		SO_2 (pphm)			NO_2 (pphm)			Ozone (pphm)		
		Annual Geometric Mean	Maximum 24-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean
60402R	1982	43	107[b]	1.2[b]	6	23[b]	2.2	7	26[c]	1.4	4[c]	11[c]
	1983	41	119	d	6	14	2.3	6	15	1.8[c]	6[c]	14[c,e]
	1984	38	161[c]	d	7[b]	20[b]	2.6	7	13	1.6[c]	5[c]	14[c,e]
60403I	1982	77[c,e]	205[c]	-	3	11	3.2[b]	8	12	1.2	5[c]	10[c]
	1983	53	179[c]	d	3	8	3.0	9	18	1.3	6[c]	11[c]
	1984	64[b]	139[c]	d	5	10	3.4[b]	9	12	1.2	5[c]	9[c]
60409R	1982	47	147[c]	d	4	13	-	-	-	-	-	-
	1983	36	95	-	4	8	-	-	-	-	-	-
	1984	41	90	d	5	15	-	-	-	-	-	-
60410R	1982	58	136[c]	d	5	22[b]	2.5	9	15	1.5	5[c]	11[c]
	1983	51	161[c]	d	5	8	1.9	7	13	1.7[c]	7[c]	16[c,e]
	1984	62[b]	208[c]	d	6	12	1.8	6	9	1.5	6[c]	14[c,e]
60412R	1982	60	158[c]	1.0	7[b]	30[b]	3.4[b]	12[c]	23[c]	-	-	-
	1983	49	144[c]	d	5	16	2.7	11	15	-	-	-
	1984	54	167[c]	d	6	17	3.6[b]	9	21	-	-	-
60413R	1982	55	154[c]	d	4	15	2.1	6	14	1.6[c]	6[c]	12[c,e]
	1983	48	162[c]	d	7[b]	47[c]	-	4	8	1.6[c]	9[c]	15[c,e]
	1984	49	159[c]	d	4	23	2.4	6	11	1.7[c]	7[c]	11[c]

TABLE 3.3 (Cont'd)

Sampling Station[a]	Year	TSP ($\mu g/m^3$)		SO_2 (pphm)			NO_2 (pphm)			Ozone (pphm)		
		Annual Geometric Mean	Maximum 24-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean
60414I	1982	94[c,e]	230[c]	d	6	16	3.1[b]	9	15	1.1	4[c]	8[b]
	1983	82[c,e]	173[c]	-	7[b]	17	3.0	7	10	1.2	5[c]	11[c]
	1984	112[c,e]	428[e,f]	-	5	15	3.0	7	11	1.2	5[c]	9[c]
60415R	1982	66[b]	144[c]	d	7[b]	26[b]	2.6	6	11	1.4	5[c]	10[c]
	1983	68[b]	229[c]	d	6	34[b]	2.6	6	11	1.7[c]	6[c]	15[c,e]
	1094	62[b]	328[c]	d	5	35[c]	2.6	6	10	1.5	5[c]	11[c]
60517C	1982	56	124[c]	d	6	22[b]	2.7	10	15	1.4	5[c]	11[c]
	1983	59	144[c]	d	6	11	2.5	7	15	1.7[c]	7[c]	15[c,e]
	1984	57	245[c]	d	9[b]	20[b]	2.7	7	13	1.7[c]	6[c]	13[c,e]

[a]The first digit of each code indicates the province in which the station is located, the second and third the city, and the last two the location within the city. Land use is denoted bvy C for commercial, R for residential, and I for industrial.

[b]Exceeds Canadian maximum desirable level.

[c]Exceeds Canadian maximum acceptable level.

[d]Calculated means are below 10 parts per billion.

[e]Exceeds U.S. health related standard.

[f]Exceeds Canadian maximum tolerable level.

Source: Ref. 8.

TABLE 3.4 Ambient Air Pollutant Concentrations for Sudbury, Ontario, 1982-1984[a]

Sampling Station[a]	Year	TSP ($\mu g/m^3$)		SO_2 (pphm)			NO_2 (pphm)			Ozone (pphm)		
		Annual Geometric Mean	Maximum 24-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean
606602R	1982	34	117	b	6	33[c]	b	3	25[c]	1.6[d]	7[c]	10[c]
	1983	29	82	b	16[c,e]	67[c]	-	3	6	1.4	6[c]	15[c,e]
	1984	28	74	b	9[d]	67[c]	-	3	8	-	6[c]	7
606605C	1982	-	120	-	-	-	-	-	-	-	-	-
	1983	40	153[c]	-	-	-	-	-	-	-	-	-
	1984	-	91	-	-	-	-	-	-	-	-	-
606606C	1982	-	-	b	10[d]	51[c]	-	-	-	-	-	-
	1983	-	-	b	23[c,e]	92[c]	-	-	-	-	-	-
	1984	-	-	b	8[d]	49[c]	-	-	-	-	-	-

[a]The first digit of each code indicates the province in which the station is located, the second and third the city, and the last two the location within the city. Land use is denoted bvy C for commercial, R for residential, and I for industrial.

[b]Calculated means are below 10 parts per billion.

[c]Exceeds Canadian maximum acceptable level.

[d]Exceeds Canadian maximum desirable level.

[e]Exceeds U.S. health-related standard.

Source: Ref. 8.

TABLE 3.5 Ambient Air Pollutant Concentrations for Vancouver, British Columbia, 1982-1984[a]

Sampling Station[a]	Year	TSP ($\mu g/m^3$)		SO_2 (pphm)			NO_2 (pphm)			Ozone (pphm)		
		Annual Geometric Mean	Maximum 24-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean
00102R	1982	48	144[b]	-	-	-	-	-	-	-	-	-
	1983	35	92	-	-	-	-	-	-	-	-	-
	1984	43	153[b]	-	-	-	-	-	-	-	-	-
00104R	1982	42	187[b]	-	-	-	-	-	-	-	-	-
	1983	34	107	-	-	-	-	-	-	-	-	-
	1984	27	117	-	-	-	-	-	-	-	-	-
00106R	1982	38	107	c	2	9	2.6	6	12	1.0	4[b]	8
	1983	35	83	-	2	4	2.6	6	12	0.8	3[b]	10
	1984	31	128[b]	c	2	4	2.6	8	16	0.9	4[b]	8
00108I	1982	53	184[b]	-	-	-	-	-	-	1.2	4[b]	6
	1983	46	120	-	-	-	-	8	12	-	3[b]	6
	1984	41	160[b]	-	-	-	2.0	6	9	1.0	3[b]	6
00109C	1982	55	130[b]	-	-	-	-	-	-	-	-	-
	1983	41	87	-	-	-	-	-	-	-	-	-
	1984	45	168[b]	-	-	-	-	-	-	-	-	-
00110R	1982	34	97	c	5	8	2.2	7	16	1.4	4[b]	8
	1983	26	90	c	8[d]	31[d]	-	5	13	-	4[b]	8
	1984	27	101	c	4	23[d]	2.1	5	13	1.1	3[b]	8
00111I	1982	39	96	c	3	8	2.1	10	18	-	6[b]	13[b,e]
	1983	34	86	c	2	4	2.0	5	11	1.4	8[b]	17[e,f]
	1984	30	94	c	3	5	2.1	5	11	-	4[b]	11[b]
00112C	1982	-	-	-	2	6	-	7	12	-	3[b]	5
	1983	-	-	c	2	5	2.9	5	10	c	3[b]	6
	1984	-	-	c	1	6	-	13[b]	27[b]	c	2[b]	4
00113I	1982	48	179[b]	-	-	-	-	-	-	-	-	-
	1983	41	133[b]	-	-	-	-	-	-	-	-	-
	1984	33	129[b]	-	-	-	-	-	-	-	-	-

TABLE 3.5 (Cont'd)

Sampling Station[a]	Year	TSP ($\mu g/m^3$)		SO_2 (pphm)			NO_2 (pphm)			Ozone (pphm)		
		Annual Geometric Mean	Maximum 24-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean	Annual Arithmetic Mean	Maximum 24-h Mean	Maximum 1-h Mean
00114C	1982	40	148[b]	-	-	-	-	-	-	-	-	-
	1983	32	121[b]	-	-	-	-	-	-	-	-	-
	1984	29	115	-	-	-	-	-	-	-	-	-
00115R	1982	-	155[b]	-	-	-	-	-	-	-	-	-
	1983	30	92	-	-	-	-	-	-	-	-	-
	1984	28	86	-	-	-	-	-	-	-	-	-
00116R	1982	36	84	-	-	-	-	-	-	-	-	-
	1983	-	100	-	-	-	-	-	-	-	-	-
	1984	29	82	-	-	-	-	-	-	-	-	-
00117R	1982	40	121[b]	-	-	-	-	-	-	-	-	-
	1983	34	94	-	-	-	-	-	-	-	-	-
	1984	-	113	-	-	-	-	-	-	-	-	-

[a]The first digit of each code indicates the province in which the station is located, the second and third the city, and the last two the location within the city. Land use is denoted bvy C for commercial, R for residential, and I for industrial.

[b]Exceeds Canadian maximum acceptable level.

[c]Calculated means are below 10 parts per billion.

[d]Exceeds Canadian maximum desirable level.

[e]Exceeds U.S. EPA health-related standard.

[f]Exceeds Canadian maximum tolerable level.

Source: Ref. 8.

station reported SO_2 levels (in 1982 and 1983) that exceeded both the Canadian maximum acceptable 24-h level and the U.S. standard.

In Toronto (see Table 3.3), ozone concentrations showed no significant trend change between 1982 and 1984. High levels of ozone exceeding the Canadian maximum acceptable level were reported at seven of the eight sampling stations reporting ozone concentrations in 1984. Also, some sampling stations have reported ozone levels that exceed the U.S. standard. Most sampling stations reported levels of TSP that exceed the Canadian maximum desirable 24-h level. Only one station reported a consistent annual and short-term level of TSP that exceeds both the U.S. standard and the Canadian guideline limit. Two stations reported SO_2 levels that exceeded the Canadian maximum desirable level in 1983.

Table 3.4 indicates that Sudbury, Ontario, has SO_2 levels that have almost consistently exceeded the Canadian maximum desirable 1-h level and the 24-h level in 1983 only. Ozone concentrations at the one station reporting such concentrations indicate that they were consistently in excess of the 24-h guideline level. Table 3.5 indicates that Vancouver has had problems meeting the Canadian maximum desirable levels for ozone and TSP, in particular, the 24-h maximum levels.

3.2 AIR POLLUTION EMISSIONS

3.2.1 Recent Trends

The SO_2 emission history between 1950 and 1980 for U.S. Regions 1-5 (i.e., EPA regions) and eastern Canada, i.e., Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, and Newfoundland, is displayed in Fig. 3.1.[9] (The location of these areas is displayed in Fig. 3.2.) The U.S. emission estimates are available[10] in 5-yr increments between 1950 and 1980 and are considered more reliable than those before 1950 because of more-complete information on fuel consumption by state. (These state-level data were aggregated by region and then plotted in Fig. 3.1.) The Canadian emission data were obtained by province and subregion from three sources: (1) the U.S.-Canadian Memorandum of Intent (MOI) Work Group 3B final report,[11] (2) production and emission estimates from copper-nickel smelter records in Canada for 1950-2000, reported by Environment Canada,[12] and (3) data from *Canada Energy Mines & Resources.*[13] These sources did not include emissions from domestic Canadian activities because it was assumed that the contribution was too small to be of significance.

Figure 3.1 indicates that estimated SO_2 emissions in the U.S. regions depicted in Fig. 3.2 began to increase after 1955. These emissions were dominated by sources in Region 5, where total emissions peaked at over 9 million metric tons (t) in 1965 and remained there until 1970, when they began to decline. Estimated SO_2 emissions in U.S. Regions 2 and 3 paralleled the pre-1965 trend of Region 5 but began to decline earlier, i.e., after 1965. In Region 1, estimated emissions increased gradually until 1970, then declined, while in Region 4, there was a significant upward trend until 1975, when the trend reversed. In eastern Canada, emissions demonstrated a fairly steady increase until 1970, though the rate of increase became less pronounced between 1960 and 1970. After

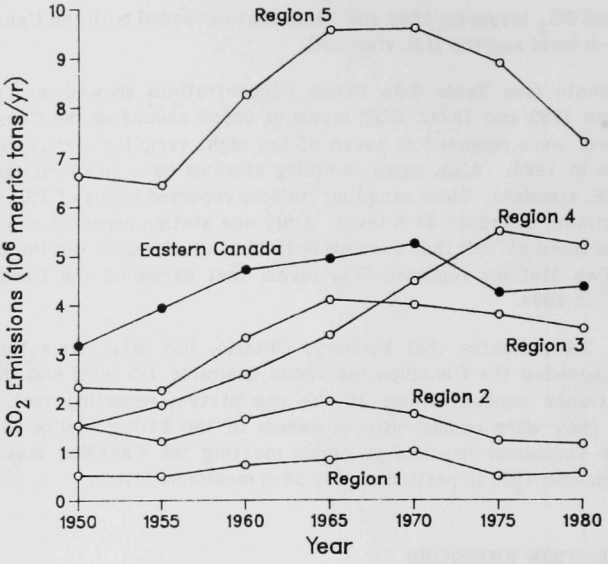

FIGURE 3.1 SO_2 Emission History for U.S. Regions 1-5 and Eastern Canada (Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, and Newfoundland)[9,10]

1970, eastern Canadian emissions exhibited a pronounced decrease, but then began to increase again in 1975. In summary, SO_2 emissions in U.S. Regions 1-5 (dominated by Region 5) and in eastern Canada together demonstrated an increasing trend until 1970 and a declining trend afterwards.

Although Fig. 3.1 displays the trend in SO_2 emissions over a fairly long period of time (i.e., 30 years), the second half of this period, 1965-1980, provides a more current perspective, yet is still long enough for trend analysis. During this period, estimated SO_2 emissions in all five eastern U.S. regions showed a net decrease, except for Region 4, which showed a rather substantial percentage increase. Total estimated SO_2 emissions in eastern Canada also exhibited a net decrease over this period. The net change in SO_2 emissions for all the regions plotted in Fig. 3.1 is summarized in Table 3.6 for the period 1965-1980. In terms of the magnitude of emissions, Fig. 3.1 clearly indicates that the decrease in emissions in Region 5 and the increase in emissions in Region 4 are the most significant changes.

3.2.2 Emission Reduction Program

The federal Canadian government and six provincial governments (Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, and Newfoundland) reached an agreement

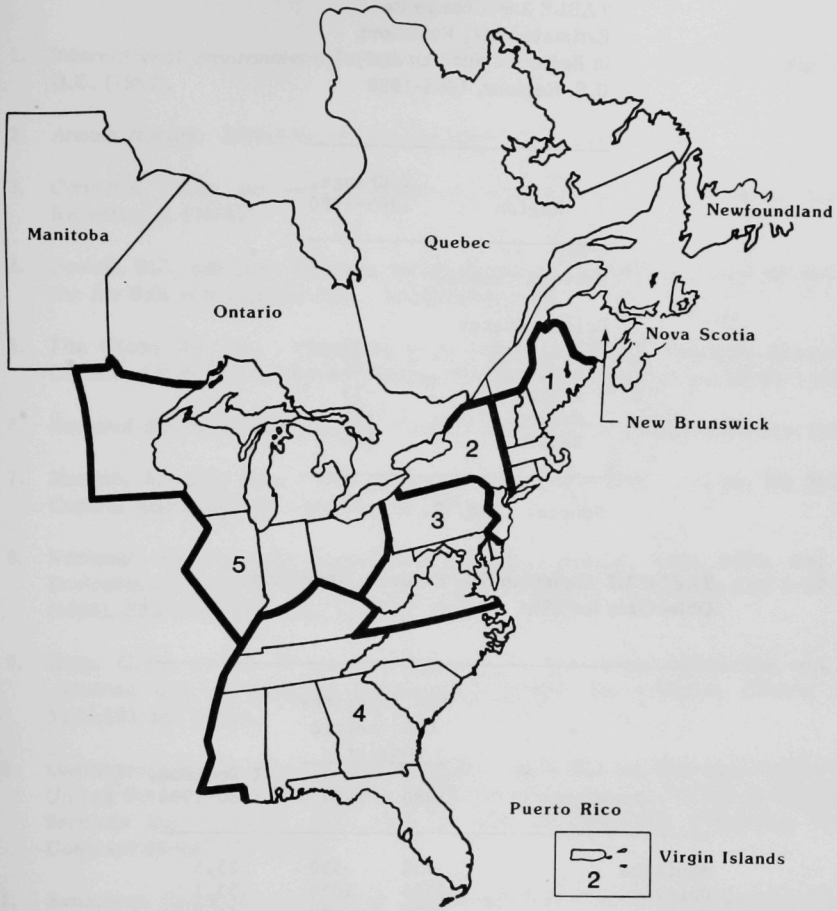

FIGURE 3.2 Map of U.S. Regions 1-5 and Eastern Canada

in February 1985 to reduce provincial SO_2 emissions in order to achieve the wet sulfate deposition goal of no more than 20 kg/ha/yr. The specific reduction objectives for 1994 are itemized by province in Table 3.7. The program calls for the abatement of 1,897,000 t of SO_2 emissions by 1994, which would represent a 42% reduction from the 1980 emission level of 4,516,000 t. The greatest reduction in emissions, in both absolute and percentage terms, is expected to occur in Ontario and Quebec. Ontario is scheduled to reduce SO_2 emissions by 1,164,000 t and Quebec by 485,000 t; these amounts represent 61% and 26%, respectively, of the total Canadian emission reduction objective.

TABLE 3.6 Change in Estimated SO_2 Emissions in Eastern Canadian and U.S. Regions, 1965-1980

Region	% Change, 1965-1980
Eastern Canada	-12
United States	
Region 1	-35
Region 2	-45
Region 3	-15
Region 4	+55
Region 5	-24

Source: Ref. 9.

TABLE 3.7 Canadian SO_2 Emission Reduction Objectives for 1994

Province	SO_2 Emissions (10^3 metric tons/yr)		% Decline, 1980-1994
	1980	1994[a]	
Manitoba	738	550	25.5
Ontario	2194	1030	53.1
Quebec	1085	600	44.7
New Brunswick	215	185	13.6
Prince Edward Island	6	5	16.7
Nova Scotia	219	204	6.8
Newfoundland	59	45	23.7
Total	4516	2619	42.0

[a]Emission objectives.

Source: Ref. 14.

REFERENCES

1. *International Environment Reporter*, Bureau of National Affairs Inc., Washington, D.C. (1982).

2. *Annual Report: 1979/1980*, Environment Canada, Ottawa (1981a).

3. *Canadian Clean Air Act*, Section 21, reprinted in International Environment Reporter, p. 51:1905.

4. Powell, R.J., and L.M. Wharton, *Development of the Canadian Clean Air Act*, J. of the Air Pollution Control Assn., *32*(1):62-65 (1982).

5. *The Clean Air Act: Compilation of Regulations and Guidelines*, Environment Canada, Air Pollution Control Directorate, Ottawa, Report EPS 1-AP-81-1 (1981).

6. *National Emission Guidelines for Thermal Power Stations*, Canada Gazette (1981).

7. Manson, A., *Acid Rain Policy: The Canadian Perspective*, J. of the Air Pollution Control Assn., *35*(3):205-209 (March 1985).

8. *National Air Pollution Surveillance Annual Summary, 1982, 1983, and 1984*, Environment Canada, Environmental Protection Service, Reports EPS 5-EP-83-13 (1983), EPS 7/AP/13 (1984), and EPS 7/AP/16 (1985).

9. Hidy, G.M., et al., *Trends in Historical Acid Precursor Emissions and Their Airborne and Precipitation Products*, J. of the Air Pollution Control Assn., *31*(4):333-354 (1984).

10. Gschwandtner, G., et al., *Historic Emissions of Sulfur and Nitrogen Oxides in the United States from 1900 to 1980*, draft report prepared by Pacific Environmental Services Inc., Durham, N.C., for the U.S. Environmental Protection Agency, Contract 68-02-3311 (1983).

11. *Emissions, Costs and Engineering Assessment*, U.S.-Canada Memorandum of Intent, Work Group 3B Final Report (1982).

12. *Copper-Nickel Smelter Complexes in Canada 1981: SO_2 Emissions (1950-2000)*, Environment Canada, Environmental Protection Service, Report EPS 3-AP-80-5 (1981).

13. Warfe, B., *Canada Energy Mines and Resources*, cited in Ref. 9.

14. News release from the Minister's Office, Environment Canada, Publication PR-HQ-085-16 (March 6, 1985).